Effect of Length and Porosity on the Acoustic Performance of Concentric Tube Resonators

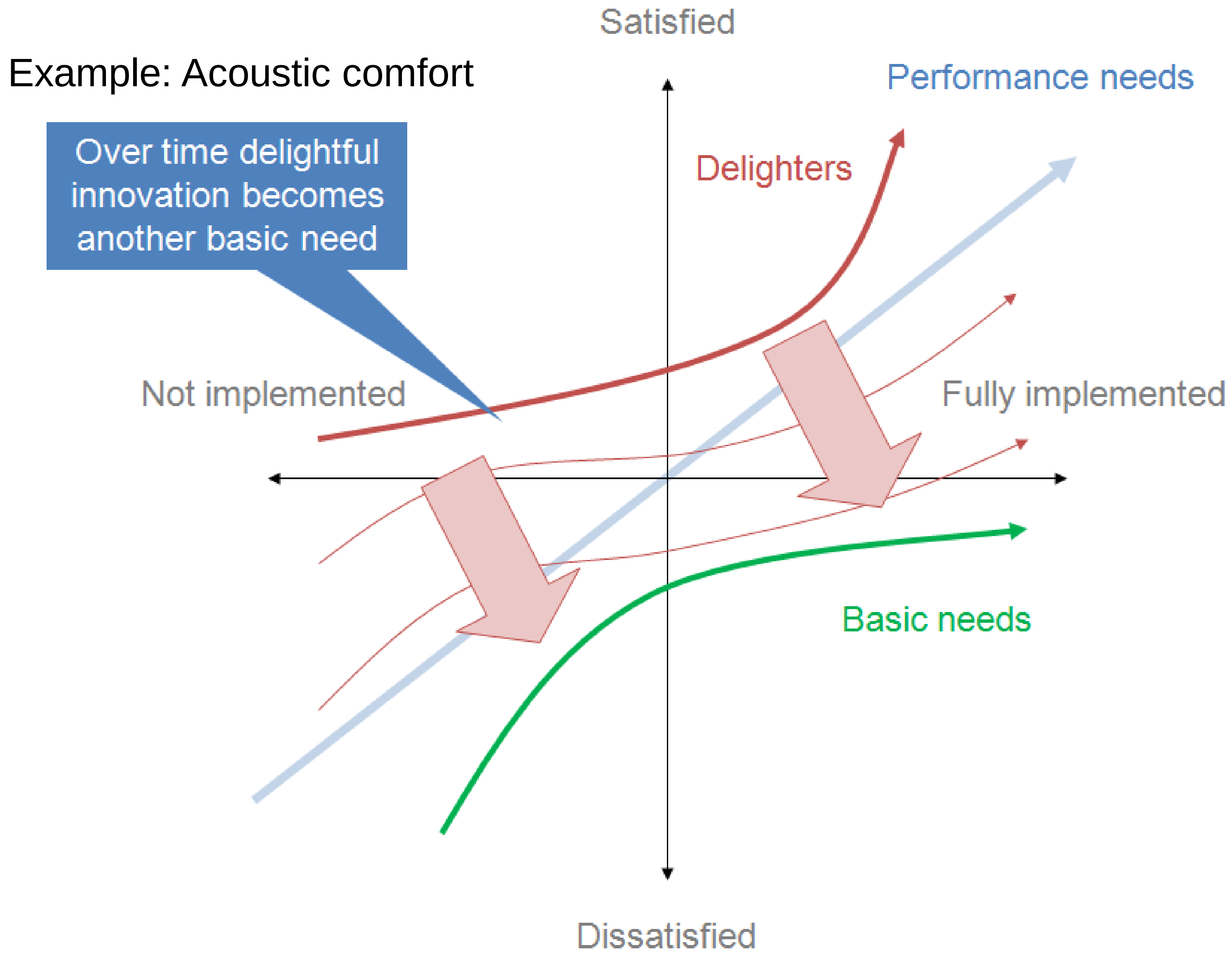
COMSOL CONFERENCE

2015 PUNE

Contents

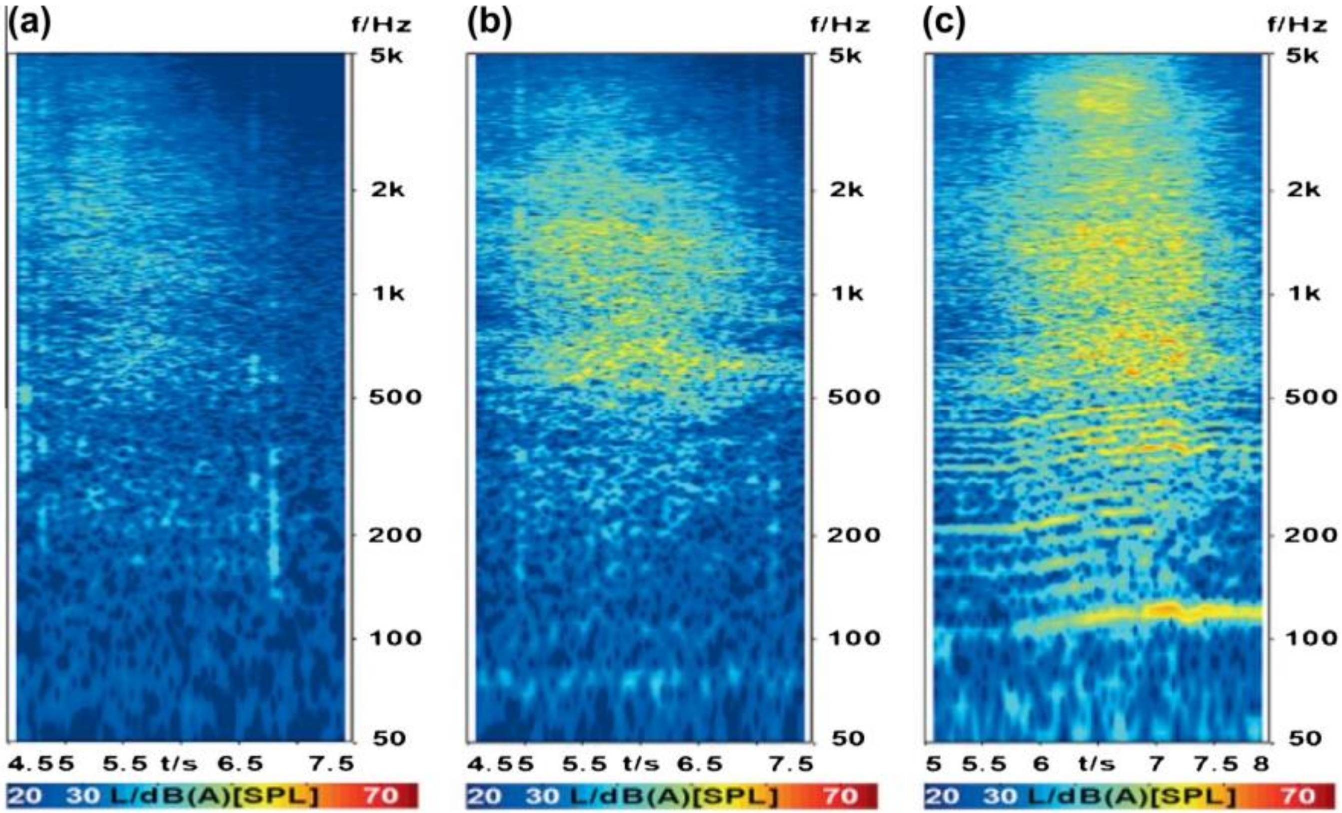
Motivation

- Kano Model of Customer Satisfaction



Motivation

- ISO 362 Pass-By noise test (frequency content)*



Engine orders dominate

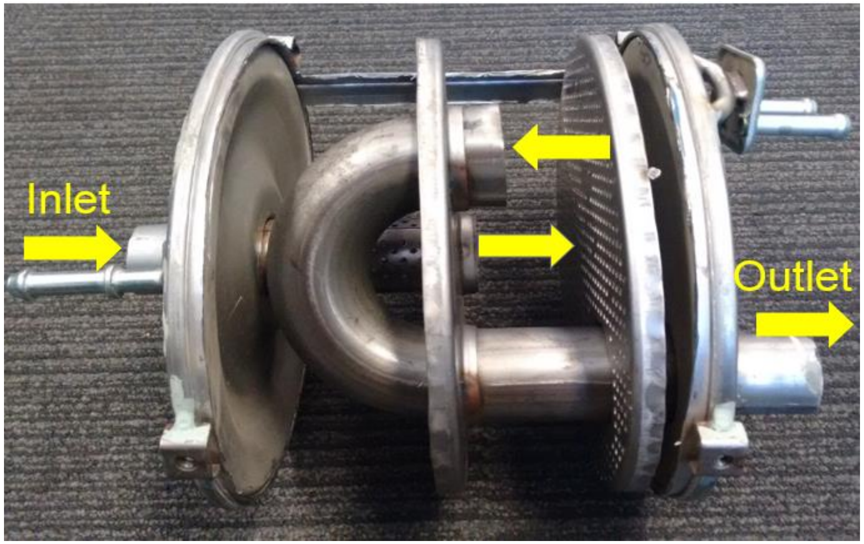
Fig. 7. Colourmap plots of different pass-by noise tests: (a) engine switched off and slick tyres; (b) engine switched off with standard tyres; (c) ISO 362 test [12] (reprinted from 'Alt N, Wolff K, Eisele G, Pichot F. Fahrzeugaussengeräuschsimulation (Vehicle exterior noise simulation). Automobiltechnische Zeitschrift 2006; 108:832-36.' With kind permission of Dr Alt).

- Frequency below 500 Hz is dominated by the **engine orders**, which are directly related to the **intake and exhaust systems**.

*M.E. Braun et al. / Applied Acoustics 74 (2013) 1241–1265

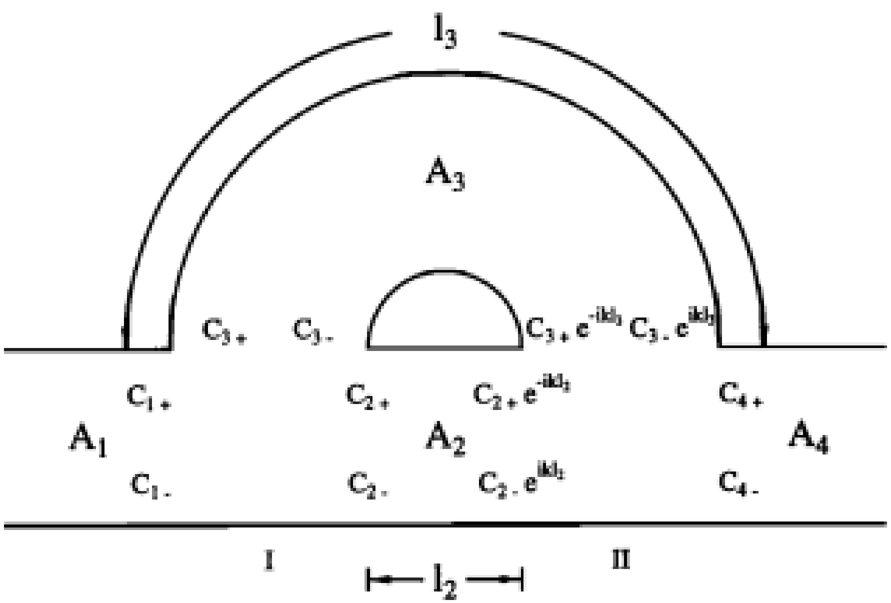
Motivation

- CTR is an essential element of today's automotive mufflers



Theory

- Herschel –Quincke Tube Phenomenon (Herschel, 1833)

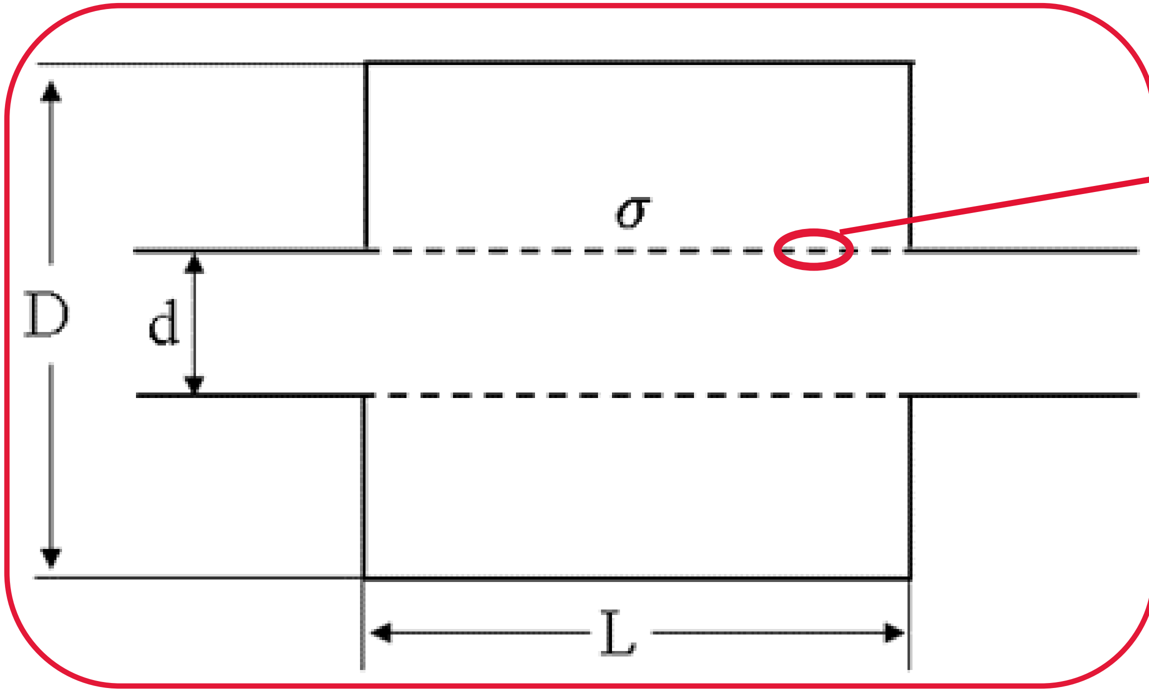


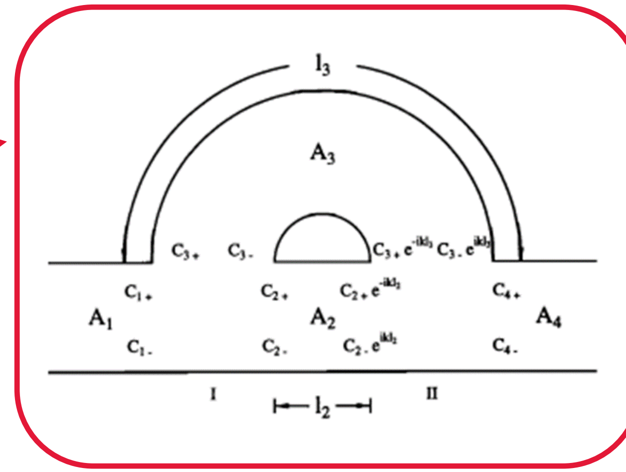
(Selamet et al. 1994)

- Conditions for destructive interference: $l_3 - l_2 = \frac{(2n-1)\lambda}{2}$ and $l_3 + l_2 = m\lambda$
- Assumptions: $A_1 = A_2 + A_3$ and $A_1 = A_4$
- Plane wave propagation!

Theory

- Application of Herschel –Quincke Tube in CTR





- Combinations of H-QT

$\frac{L}{D}$ limit for plane wave propagation? Acoustically short

Governing Equations

- 3-D Helmholtz equation with no source terms

$$\nabla.\left(-\frac{\nabla p}{\rho}\right)-\frac{\omega^2 p}{\rho c^2}=0$$

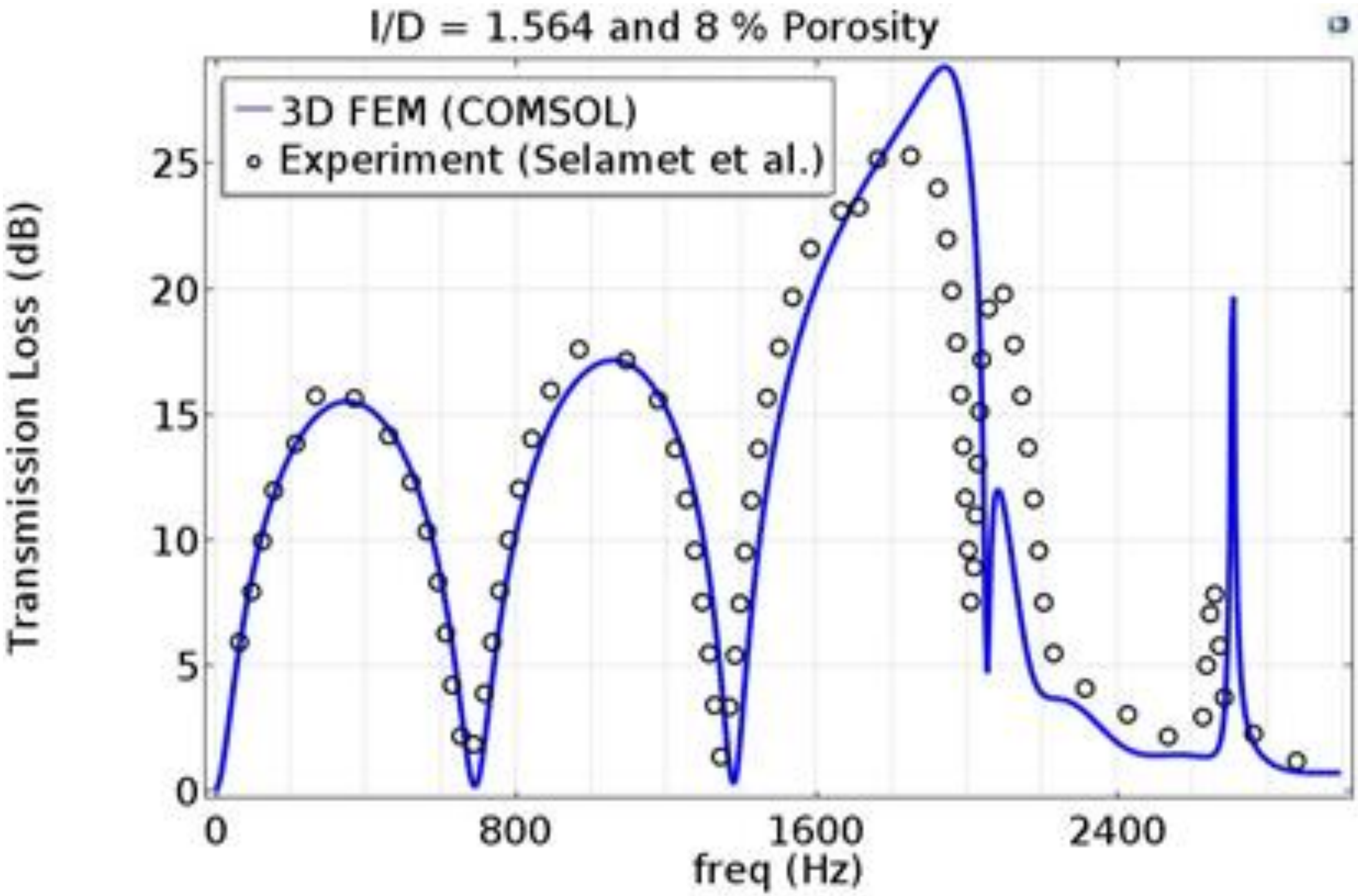
- Transmission Loss

$$TL = 10\log_{10}\left(\frac{W_i}{W_o}\right)\ dB\,, W_i = \oint \frac{p^2}{2\rho c}\ \text{ and } W_o = \oint \frac{{p_c}^2}{2\rho c}$$

- Perforate impedance, (Sullivan and Crocker, 1978)

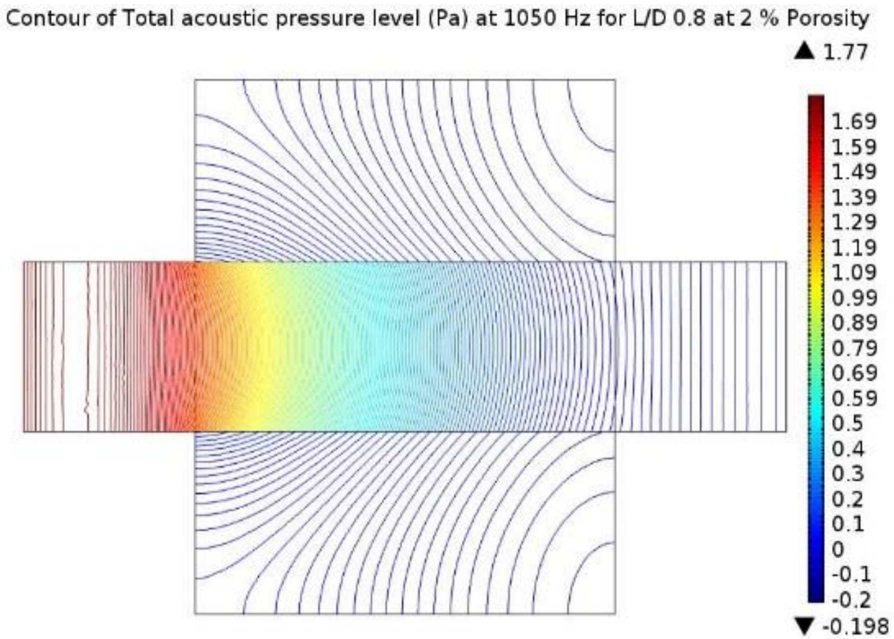
$$\varsigma_p = [0.006 + jk_0(t + 0.75d_h)]/\sigma$$

COMSOL Model Validation

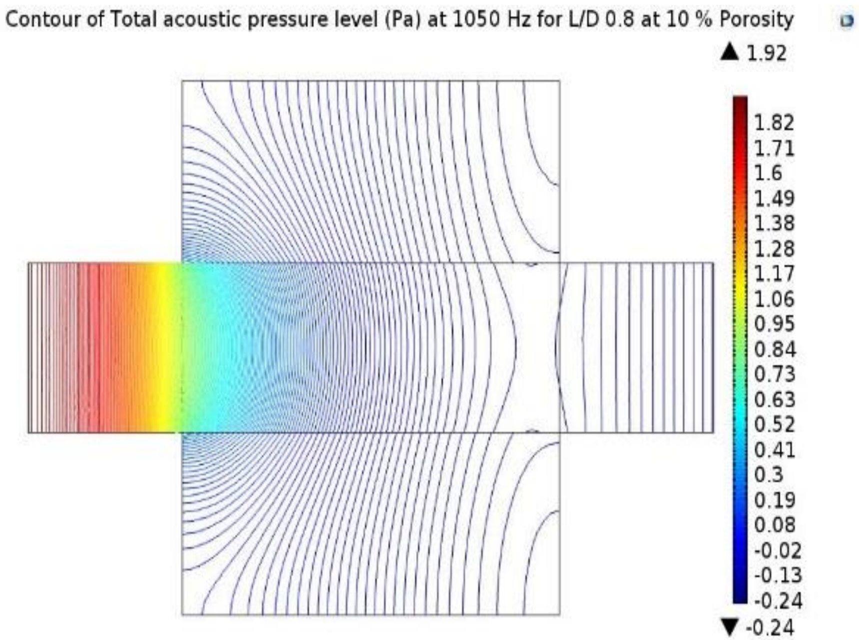


Ref: Selamet, Ahmet, I. J. Lee, Z. L. Ji, and N. T. Huff. Acoustic attenuation performance of perforated absorbing silencers. No. 2001-01-1435. *SAE Technical Paper*, doi:10.4271/2001-01-1435 (2001)

Results

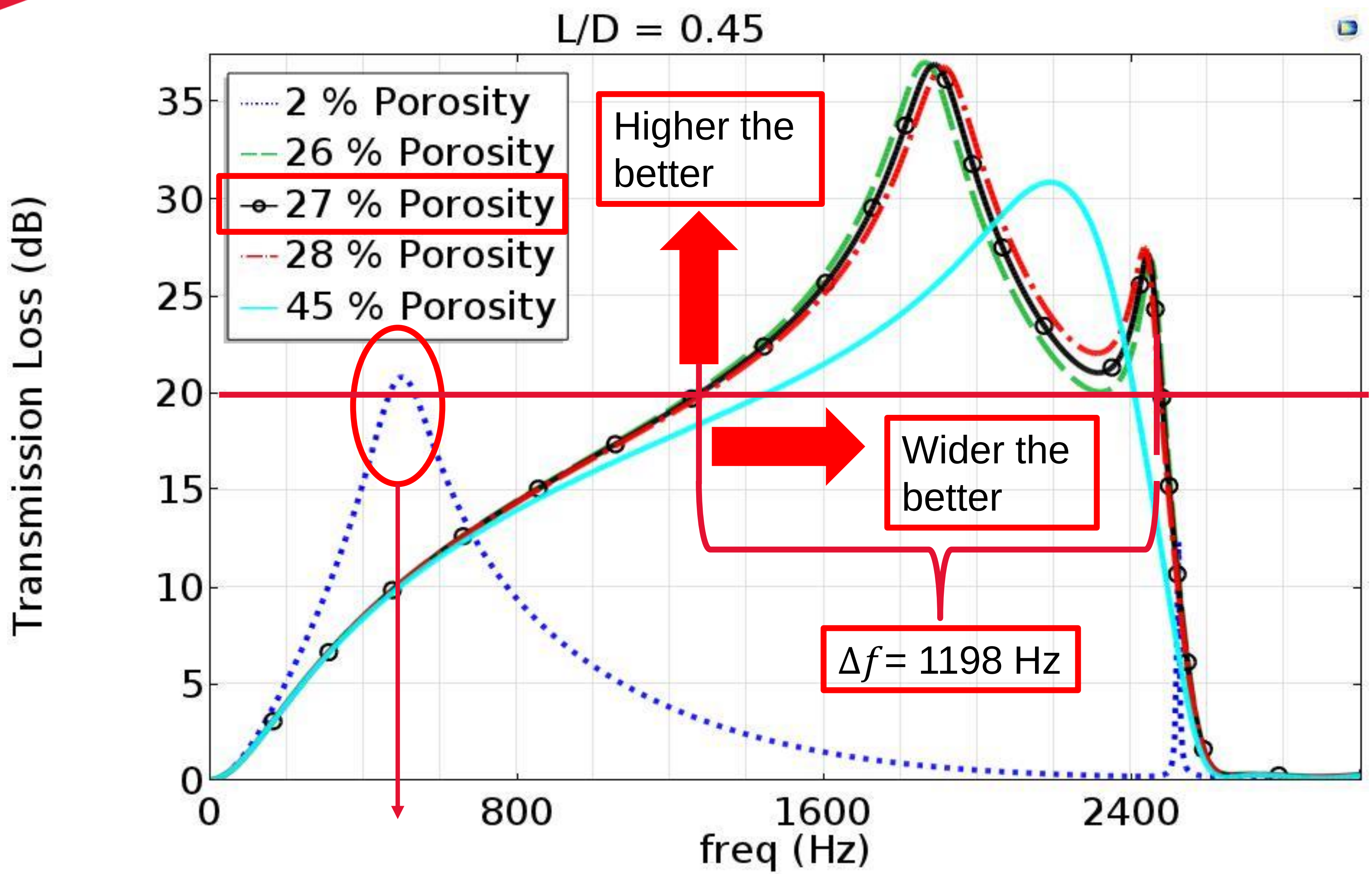


- The acoustic wave propagation multi-dimensional.



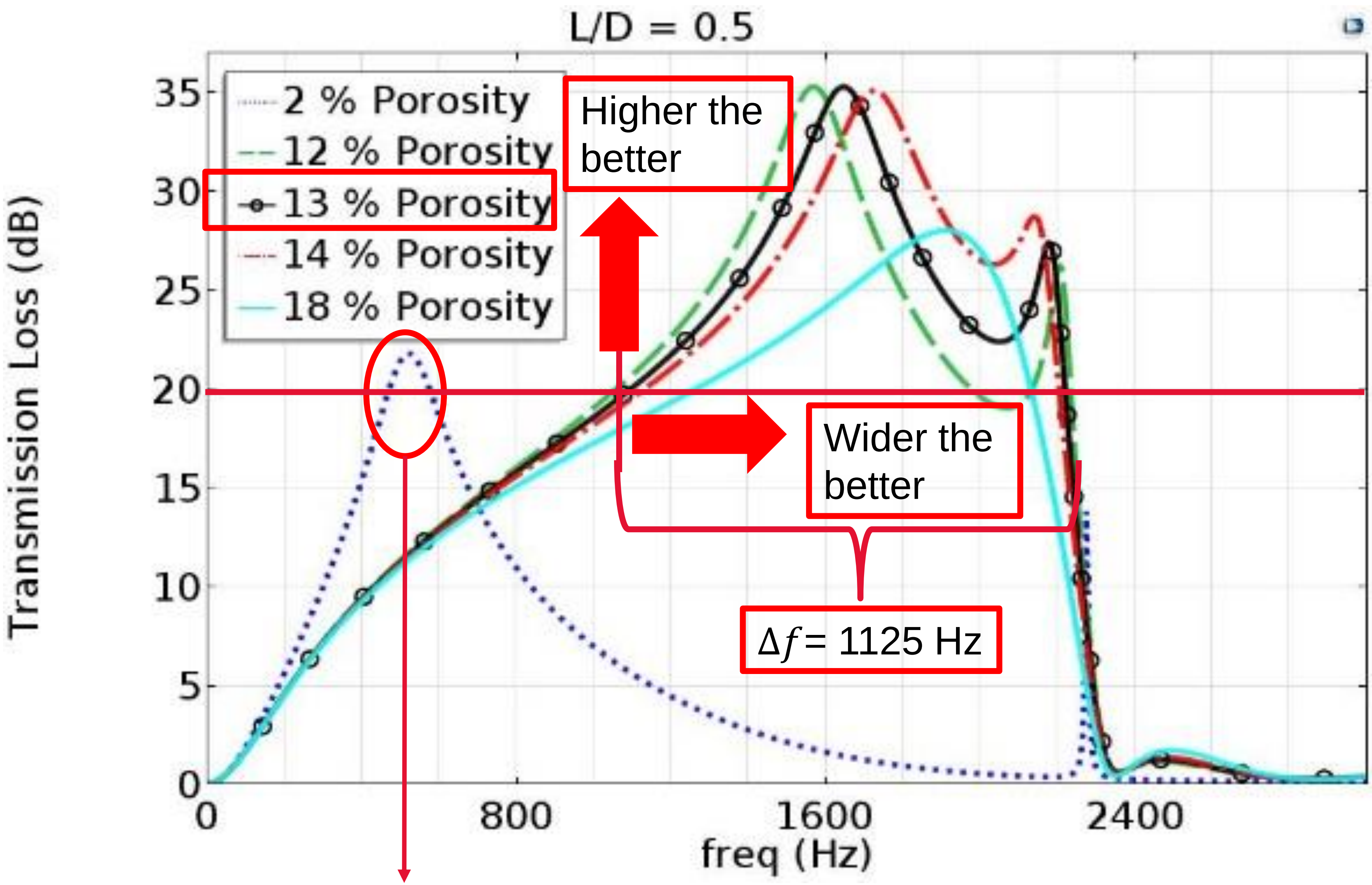
- The plane wave assumption is not applicable here.

Results



Helmholtz Resonance behavior, **Undesirable!**

Results



Helmholtz Resonance behavior, **Undesirable!**

Results

- Summary of results

Model	$\mathbf{L/D}$	$\boldsymbol{\sigma}$ **(%)**	**Frequency bandwidth of TL above 20 dB (Hz)**
1	0.450	27	1198
2	0.500	13	1125
3	0.612	6	930
4	0.700	4	820
5	0.800	3	667

- Empirical formula for Porosity as a function of L/D ratio.

$$\sigma = 0.03739(L/D)^{-8.075} + 3.288$$

Conclusions

- The effect of length and porosity on the acoustic performance of acoustically short CTR is quantitatively discussed for the first time.

- An empirical formula is presented to estimate the optimum porosity as a function of the L/D ratio for wideband Transmission Loss.

- The optimum porosity decreases as the L/D ratio increases.

- L/D ratio of 0.205 behave as short resonator for all possible porosities

Q&A


Thank you